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PROGRAM DETERMINATION OF THE LOW FREQUENCY GEOMAGNETIC FIELD AND THEIR INFLUENCE ON BIOLOGICAL OBJECTS

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Abstract. The program of computations of spectrum of the geomagnetical field is developed. It was confirmed, that the most values of tension of the geomagnetical field at magnetic storms arise up on frequencies below 1 Hz. On the basis of an algorithm developed the characteristics of the super low-frequency geomagnetic field at the frequency range < 1 Hz are calculated. The analysis at frequencies 0.1, 0.5, 0.01, 0.05, 0.001, 0.0001 Hz allows to reveal the largest intensity of the low-frequency geomagnetic field at 0.0001 Hz. Its oscillation rate is most sensitive for biological organisms to the magnetic storm occurrence. Some examples of influencing of low frequency fluctuations of the geomagnetical field on biological objects are considered. The ways of their computations are given. Biological objects which can possess sensitiveness to influences of the weak magnetic fields are considered. The results obtained are used to consider some aspects of the mechanism of the low-frequency geomagnetic field influence on biological objects.

Keywords: geomagnetic field, low frequency fluctuations, sensitiveness of biological objects.

Introduction

There is the growing amount of evidence of the influence of the geomagnetic field (GMF) on biological objects [1, 2]. That can be followed as a direct effect of the variable GMF, as some kind of indirect signatures of behaviour of biological objects. The investigations are based on the analysis of so-called magnetic storms occurring in the GMF as apparent disturbances. Nowadays it is known that occurrence of magnetic storms is linked to solar activity enhancements. The Sun-Earth relationships and their manifestations in the quality of the environment is a reason to speak of the space weather [2, 3]. The bioactivity of magnetic storms is studied regarding liker illness states and behaviour peculiarities or with respect to various vital activity parameters and functions of biological objects [3]. The model experiments to study the magnetic field influence on biological objects, when GMF amplitude characteristics in the frequency range of 1–100 Hz are irritated, appears to be contradictory [4]. A number of questions arise, the principal ones being as follows:

- what is a reason of a changing character of response to magnetic storms even for the same biological objects studied?
- why a repetition of results obtained is rather ambiguous?

To answer them we have to be aware of the complexity of these interdisciplinary problems. First of all, in spite of a high level of our understanding of the GMF variability that is a factor of high probability as to its environmental effects. The GMF fluctuations change widely in the amplitude and frequency during day and night. The trend of such changes can also change. To our opinion, the amplitude-frequency characteristics as such (considered in their unity) is a way to understand the GMF bioeffects [5]. Without doubt, the concomitant circumstances of the environment as well as local GMF anomalies, artificial electromagnetic pollution, the latitude dependence of GMF fluctuations have to be taken into the account [6]. On the other hand, the response of biological objects is directly linked to the response of both water and biological molecules to the variable GMF. It is of interest to study the GMF amplitude range changes at different frequencies with regard to their bioactivity

effects (e.g. water quality and response of biological molecules). This approach can help to specify molecular and/or cellular sensitivity to varying GMF parameters and to verify model mechanisms of bioactivity of the GMF with necessary experimental confirmation. In this study some characteristics of the super low-frequency GMF which are likely to influence biological objects are thoroughly considered [3, 4].

The approach and method used

If we remind the distribution of energy as a function of the GMF frequency variations the dependence of amplitudes on frequency of widely known regular (known as Pc 1–5) and irregular variations (known as Pi 1–2) in the GMF is significant. As shown in fig. 1 [1] a number of amplitude maxima reveals the trend of enhancing amplitudes as a function of decreasing frequencies for the frequency interval f < 1 Hz. In addition, amplitudes increase monotonically within the range of values of 4-fold orders, namely from 0.05 nT up to 500 nT at f = 0.001 Hz [1, 3].

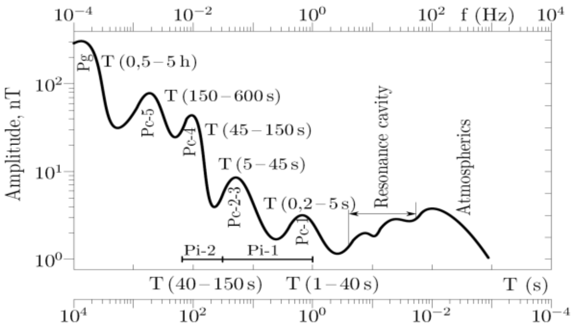

Fig. 1. The spectrum scheme of the GMF variations within the frequency range ⟨10^{-4}, 10^{4} Hz⟩ (scales are logarithmic).

Individual amplitude (nT) (vertical axis) maxima are indicated with corresponding periods of individual variations. The horizontal period axis is added (down) to the frequency one (up) discussed. Near peaks Ps and Pi there are the indicated values of periods T (c) [1].

To study more thoroughly the superlow-frequency GMF variations the calculation of amplitudes for f < 1 Hz is performed under undisturbed and disturbed (magnetic storms) GMF. This approach is a basis to evaluate the possible response of characteristics studied in terms of the variable space weather. The method used proceeds from the algorithm worked out to analyze GMF variations using high-time resolution GMF registrations. Those are realized at geomagnetic observatories organized within the INTERMAGNET family, the Hurbanovo geomagnetic observatory being its member. The data from this mid latitude observatory (Slovak Republic) are used to investigate super low-frequency components of the GMF (LCGMF). The time interval of 2010–2014, including years of 2012 and 2013 when the Sun was active. The calculations are carried out for the GMF horizontal component X monitored in Hurbanovo. The global information on magnetic storm occurrence and storm intensity is available from the World data Centre for Geomagnetism in Kyoto (http://wdc.kugi.kyotou.ac.jp/wdc/expdata.html) for the time interval of 2010–2014 mentioned above.

The algorithm prepared carries out LFGMF calculations (in the R version) and works using the interpretator R and additional so-called Seewave-1.7.6 package. The “fft” and “signal” packages are also deposited, which allows to process discrete data including their modelling, filtration and Fourier transform. The free inclusion of these packages is realized by means of repositories (CRAN) answering on the command installed package (“packet”). The output data of 200 Kb are a result of processing of 3 Mb data. The frequencies of 0.1, 0.5, 0.01, 0.05, 0.001, 0.005 and 0.0001 Hz are considered. The mean amplitude values and their oscillation range are calculated for each frequency f1, f2, …. f6, using low-frequency filter from the package Seewave (ffilter).

Worthy to note that the GMF ultralow-frequency variations chosen are of interest since the bioeffective frequencies of ⟨0.03 - 1 Hz⟩ characterizing the cation resonances (magnetically generated magnetic field intensity being similar to that of the LFGMF), which regulate biochemical processes in cells. The mechanism of such resonances is of both the cyclotron [7] and parametric character [8].

The option and utilization of filtration is of high degree of its adaptation for the data

processing and allows to follow GMF fluctuations at a chosen frequency during the 24-hour intervals considered for conditions of both the undisturbed and disturbed (magnetic storm) GMF.

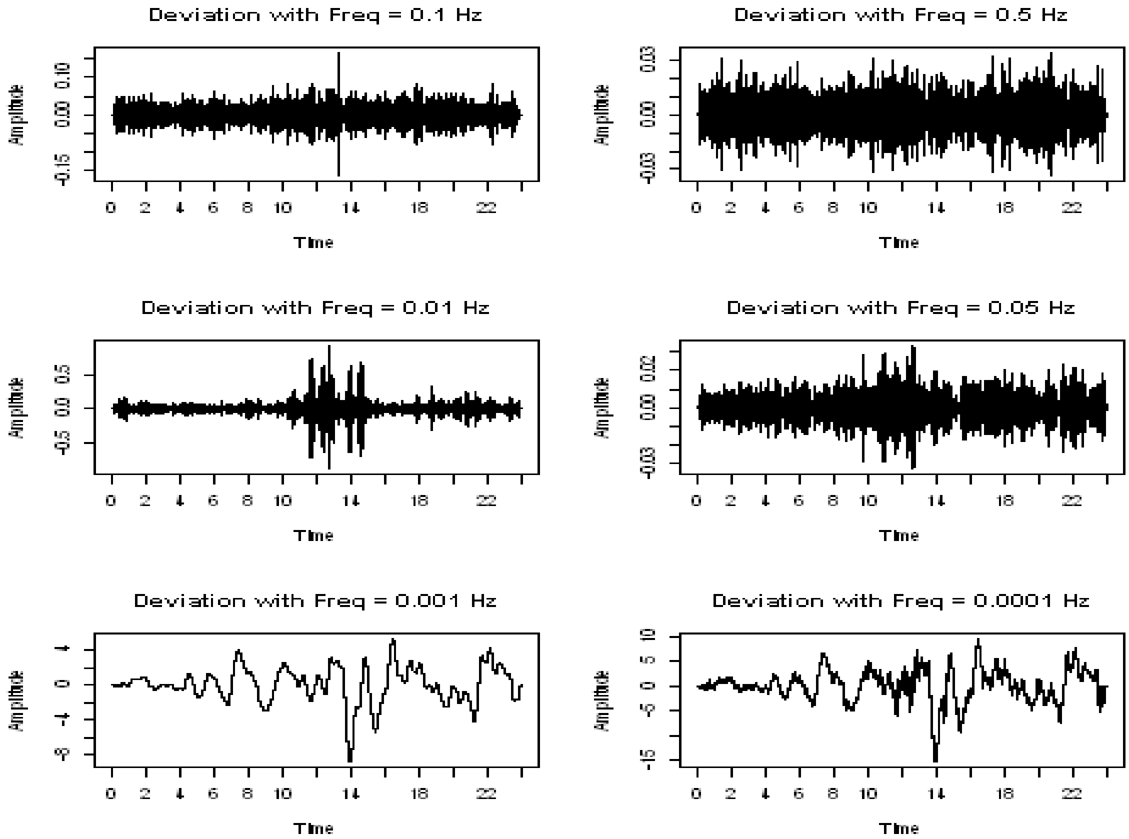

Fig. 2. Oscillation plots of the LFGMF amplitudes at frequencies f1, f2, …, f6 (0.1, 0.5, …, 0.0001 Hz) during 1 Jan 2014

Results obtained and discussion

The results of calculations are collected in 8 files (PNG format). Six of them show GMF variations at individual frequencies (Fig. 2). In addition the mean LFGMF value during successive 2-hour intervals along with summarized ones at the frequency of 0.0001 Hz for a given 24-hour interval considered are collected in last 2 files. As expected, the LFGMF amplitudes calculated at f1, f2, …, f6 increase with the decreasing frequency. The largest amplitude is at 0.0001 Hz its oscillation range being ⟨-15 ÷ 10 nT⟩. The comparison of the LFGMF amplitudes and their oscillation ranges at individual frequencies on a daily basis shows the differences in their plots.

Naturally, it could be expected since all the GMF quantitative characteristics including ones studied are associated with the current state of the magnetosphere. The mean oscillation values during 2 hours at 0.0001 Hz calculated on the daily basis for both the undisturbed and disturbed (in case of magnetic storms) GMF make it possible to compare them from the viewpoint of their dependence on occurrence of magnetic storms. Actually, that is real and during intense magnetic storms the LFGMF value at 0.0001 Hz oscillates within the range ⟨200 - 350 nT⟩ [3]. The dependence revealed appears to be essential when constructing a model of bioactive GMF parameters and their effectiveness to change e.g. the water quality and to modify (to some extent) dynamics of processes in biological objects. One of the outputs of the algorithm developed is a plot of the oscillation LFGMF amplitude range at 0.0001 Hz summarized on an hourly basis (Fig. 3).

The significant peak in the plot is an important signature of the magnetic storm

occurred. On the basis of the WDC Kyoto data on magnetic storms an option of days of occurrence of magnetic storms is possible. Both the Kp values and mean LFGMF intensity values at 0.0001 Hz summarized on the daily basis for the days mentioned are used to calculate the dependence between them. The relationship analyzed appears to be quite significant, the correlation coefficient being r = 0.69. That seems to be a reason for a more deep study of bioactive effects of the LFGMF characteristics.

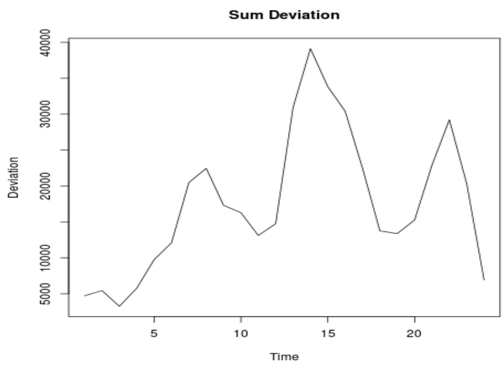

Fig. 3. A plot of the LFGMF amplitude dynamics summarized for 2-hour subintervals on 1 Jan 2014

To our opinion, bioactive effects of the variable GMF cannot be understood without the consideration of its low-frequency variations. Those might play a role of a special device which switches on a more direct mechanism of the bioactive influence, i.e. a "trigger effect" takes place [3, 4]. The channels of such influence via molecular and cellular processes, those being supposed to be modified due to the LFGMF parameters, are different. We suggest the following scheme of these complex relationships (Fig. 4).

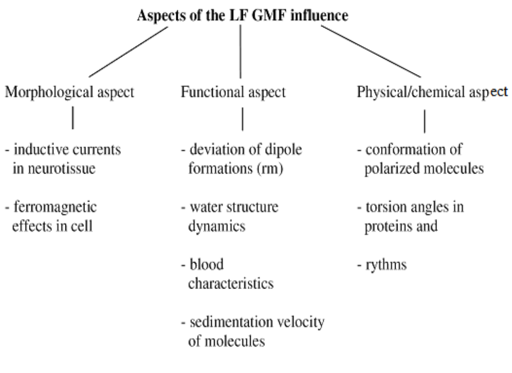

Fig. 4. Some aspects of the mechanism of the LFGMF influence on biological objects

Discussion on the LFGMF bioactivity mechanism

There is most tight relationship and condition of activities of various organs and physiological systems which actually works together being dependent upon each other, is typical for the human organism. Such a regime of coordination is due to numerous vibration processes, which take place at various levels of hierarchy of systems of the human organism – to name e.g. oxidation-renewial/restoration processes in cells or vibrating interrelations between individual organs at bioeffective frequencies [8]. The mechanical and electrical vibrations in the human organism at various frequencies can be more or less intense. The excitation of individual types of vibrations can generate/cause the excitation of other vibrations (e.g. mechanical movements of muscular structures are caused by electrical vibration processes of a spreading nerve impulse [9].

Moreover, to our opinion, an external resonance influence of vibrations of a given type (e.g. mechanical ones) is capable to cause abrupt differences in vibrations of another type (e.g. electrical ones) and vice versa. From physical point of view, a so-called “parametric resonance” which happens in a vibration circuit (inductance and capacitor with moving plates) appears to be an analogue of processes mentioned above. The periodic movements of plates change the capacity in accord with a proper frequency (the parametric resonance occurs). The response of bioobjects to electromagnetic and mechanical vibrations is specific and differs in principle. However, if bioeffective frequencies are in resonance with proper frequencies of the organism, both its ability to convert individual types of signals mutually and interrelation of its systems make it possible to perceive the vibration information of all types and then the organism responds in accord to changes of the environment. The LFGMF influence various oscillatory structures of bioobjects and as a result the resonance vibrations are likely to start in some oscillators at bioeffective frequencies [9].

The change of common frequency characteristics of external factors, the occurrence or disappearance of characteristic frequencies in the external factor as accepted by bioobjects appears to be a reason of desynchronization and disfunction of molecular and tissue activities. The character of the frequency reorganization of the organism under changing external factors defines the duration of adaptation processes. Then the response of bioobjects on magnetic storms is associated with the occurrence and disappearance of resonance frequencies during storms, when the field strength depression is of no meaning. Actually, such natural parameters of the environment as the ultralow-frequency variations of the atmospheric pressure as well as GMF manifest their bioactivity [4]. In case of low-frequency range (0.01–40 Hz) the bioeffective frequencies of external factors can be explained, as mentioned above, by the parametric resonance in cells, capillary blood vessels, mind [7 - 9].

According to the parametric resonance, the LFGMF (periods 2–240 min) can induce the resonance in biological structures chacterized by proper frequencies corresponding to periods of 1.3 ÷ 480 min. The rythms of electrical potentials of the human brain [10], sleep and endocrine system is within this range, which confirms the LFGMF bioactivity. The blood oxysaturation parameter, which is important for human activities, appears, as follows from this study, to be influenced by LFGMF. Then it is actual to open a question of the oxygen regime of tissues, of oxidation and fermentation processes. The forthcoming research needs to be focused on a more deep insight into biological processes, considering various oxygen regimes changing due the variable space weather.

Conclusion

1. Thanks to the use of filters with the set frequencies, the developed program allows to expect fluctuations of the geomagnetical field on the chosen frequency and in the dear chosen period of day at the not revolted state of the magnetic field and during magnetic storms.
2. The use of the developed program of determination of low-frequency variations of the geomagnetic field showed that with reduction of frequency from 0.5 Hz to 0,0001 Hz considerably rises to variation of amplitude of the magnetic field from -15nT to 10 nT, that confirms a theoretical curve. And during magnetic indignations can there is the increase of intensity of the magnetic field in this range of frequencies to 350 nT.
3. Increase of amplitude of the magnetic field during magnetic storms on frequency 0.0001 Hz can substantially advance influencing by morphological, functional and physical - chemical properties of water and biological systems.

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